

## Rahul Sarkar

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### Education

University of Utah, Salt Lake City, USA

*August 2015-Sept 2019*

**PhD in Metallurgical Engineering**

**CGPA: 3.99/4**

*Funded by: Department of Energy (DoE) and American Iron and Steel Institute (AISI)*

Supervisor: Prof. H.Y.Sohn

Dissertation: Interactions of iron, wustite and slags with selected refractory materials under flash ironmaking conditions

IIT Bombay, Mumbai, India

*July 2011-June 2013*

**Masters in Metallurgical Engineering and Materials Science**

**CGPA: 9.64/10**

Specialisation: Process Engineering

Supervisors: Prof. N.B.Ballal and Prof. S. Basu

Thesis: Dynamic Modelling of LD Converter Steelmaking

Jadavpur University, Kolkata, India

*July 2007- May 2011*

**Bachelors in Metallurgical Engineering**

**CGPA:7.53/10**

Undergraduate thesis supervisor: Prof. M.K.Mitra

Undergraduate thesis title: Isothermal and non-isothermal kinetics of Magnetite reduction by coking coal

### Publications

#### • Journal Publications

##### *Published articles*

- Rahul Sarkar and Zushu Li “Isothermal and non-isothermal crystallization kinetics of mould fluxes used in continuous casting of steel”, Metallurgical and Materials Transactions B, available online at: <https://link.springer.com/content/pdf/10.1007/s11663-021-02099-5.pdf>
- Rahul Sarkar and H.Y.Sohn, “Interaction of magnesia-carbon refractory with ferrous oxide under the conditions of the novel flash ironmaking technology (FIT)”, Ceramics International, Vol. 46 (2020), pp. 7204-7217.

- Rahul Sarkar and H.Y.Sohn, “Interaction of magnesia-carbon refractory with metallic iron under flash ironmaking conditions”, Journal of the European Ceramic Society, Vol. 40 (2020), pp. 529-541.
- Rahul Sarkar and H.Y.Sohn, “Interaction of iron with alumina refractory under flash ironmaking conditions”, Metallurgical and Materials Transactions B, Vol.50 (2019), pp. 2063-2076.
- Rahul Sarkar and H.Y.Sohn, “Interaction of ferrous oxide with alumina refractory under flash ironmaking conditions”, Ceramics International, Vol.45 (2019), pp.15417-15428.
- Rahul Sarkar and H.Y.Sohn, “Interactions of alumina refractory with CaO-SiO<sub>2</sub> and CaO-SiO<sub>2</sub>-FeO slags relevant to the novel flash ironmaking technology (FIT)”, Steel Research International, Vol. 90 (2019), pp. 1900104-1900116
- Rahul Sarkar and H.Y.Sohn, “Interactions of alumina and magnesia based refractories with iron melts and slags-A Review”, Metallurgical and Materials Transactions B, Vol.49(2018),pp.1860-1882
- Rahul Sarkar, Ushasi Roy and Dinabandhu Ghosh, “A model for dissolution of lime in steelmaking slags”, Metallurgical and Materials Transactions B, Vol.47 (2016), No.4, pp. 2651-2665
- M.K.Mishra, A.G.Rao, Rahul Sarkar, B.P.Kashyap and N.Prabhu, “ Effect of preaging deformation on aging characteristics of 2507 super duplex stainless steels”, Journal of Materials Engineering and Performance (JMEPEG), Vol.25(2016), pp.374-381
- Rahul Sarkar, Arunava Sengupta, Vimal Kumar and S.K.Chaudhury, “ Effects of alloying elements on the ferrite potential of Peritectic and Ultra-Low carbon steels”, Iron and Steel Institute Japan International (ISIJ Int.), Vol. 55(2015), No.4, pp. 781-790
- Rahul Sarkar, Pramod Gupta, Somnath Basu and N.B.Ballal, “Dynamic Modeling of LD converter steelmaking: Reaction modelling using Gibb’s free energy minimization”, Metallurgical and Materials Transactions B, Vol.46 (2015), No.2, pp. 961-976.

***Submitted articles and manuscripts in preparation***

- Rahul Sarkar and Zushu Li, “Isothermal crystallization kinetics of two CaO-SiO<sub>2</sub>-CaF<sub>2</sub>-based industrial mold fluxes for small degrees of undercooling, submitted in Metallurgical and Materials Transactions B.
- Rahul Sarkar and H.Y.Sohn, “Fe-Mg interdiffusion in magnesiowustite under flash ironmaking conditions”, manuscript in preparation, target journal: Journal of the European Ceramic Society.

• **Conference Proceedings**

***Published conference proceedings***

- Rahul Sarkar and H.Y.Sohn, “A model for the interaction of Fe with MgO-14.5 wt. %C refractory under flash ironmaking conditions”, Proceedings of The Minerals, Metals &

Materials Society (TMS) Annual Meeting and Exhibition to be held in San Diego in Feb 2020.

- Rahul Sarkar and H.Y.Sohn, “A kinetic model for the interaction of FeO with MgO-14.5 wt. %C refractory under the conditions of the novel flash ironmaking technology (FIT)”, accepted for publication in the Proceedings of The Minerals, Metals & Materials Society (TMS) Annual Meeting and Exhibition to be held in San Diego in Feb 2020.
- Rahul Sarkar and H.Y.Sohn, “A kinetic model for interaction of iron powder with alumina refractory relevant to the novel Flash Ironmaking Technology (FIT)”, Proceedings of Materials Science and Technology (MS&T) Conference, Portland (USA), 2019.
- Rahul Sarkar and H.Y.Sohn, “A kinetic model for interaction of iron (II) oxide with pure alumina refractory under flash ironmaking conditions”, Proceedings of Materials Science and Technology (MS&T) Conference, Portland (USA), 2019.
- Rahul Sarkar , Pramod Gupta and N.B.Ballal, “Refining of Metal Droplet in Slag using the concept of Gibbs’ Free Energy Minimization at the Slag-Metal Interface”, Proceedings of the International Conference on Science and Technology of Ironmaking and Steelmaking (STIS), Jamshedpur (India), 2013, available in CD-ROM.
- Rahul Sarkar and M.K. Mitra, “Kinetics of Reduction of Magnetite-Coking Coal Briquettes”, abstract published in proceedings of 4<sup>th</sup> National Symposium for Materials Research Scholars, MR-12, Bombay (India), 2012.

### **Professional Experience**

- **Assistant Professor, Department of MSE, IIT Kanpur** *[Sept 2021-Present]*
- **Research Fellow, WMG, University of Warwick, UK** *[Nov 2019-May 2021]*

#### ***Project Worked in:***

- **OPTILOCALHT: Optimization of local heat transfer in the continuous casting mould for casting challenging and innovative steel grades**
  - Characterization of mould powders and mould slag samples obtained from industrial trials using conventional techniques such as XRD, SEM and OM.
  - Simulation of industrial slag films in the laboratory using conventional and innovative methods.
  - Use of novel techniques such as confocal scanning laser microscopy (CSLM) and X-ray computed tomography (XCT) for characterization of crystallization, cracking, fracture strength and porosity of industrial and laboratory simulated slag films.

- **Graduate Research Assistant, University of Utah** *[August 2015-April 2019]*

*Projects Worked In:*

- **PhD Dissertation : Interactions of iron, wustite and slags with selected refractories under Flash Ironmaking conditions**
  - High temperature experimentation with iron/iron oxide and slags with selected refractory materials under flash ironmaking conditions.
  - Post-mortem analyses of quenched samples using X-ray diffraction and microscopic techniques like Optical Microscopy (OM) and Scanning Electron Microscopy (SEM).
  - Mapping of elements on the refractory cross-section using Energy Dispersive X-ray spectroscopy (EDX).
  - Development of suitable kinetics models for refractory-iron/iron oxide/slag interactions using solid-state diffusion and its validation using experimental work.
  - Calculation of kinetic parameters such as parabolic growth-rate constants, effective diffusivity and interdiffusion coefficient from the experimental data.
- **Large-Scale Laboratory Testing of Flash Ironmaking Technology**
  - Active participation in the cold and hot commissioning of large-scale bench reactor facility for flash ironmaking in the University of Utah.
  - High temperature experimentation with iron/iron oxide and selected refractory materials under flash ironmaking temperatures and gas atmospheres.
  - Participation in all experimental runs on the bench reactor from May 2016-December 2017.
  - Participation in bench reactor maintenance work from May 2016-December 2017.

- **Researcher, Tata Steel Research and development** *[July 2013-Aug 2015]*

*Projects Worked In:*

- **Development of static model to improve ferro-alloy recovery in LD 2 plant (Leader)**
  - Data collection on the existing amounts of addition of different ferro-alloys and their chill-factors.
  - Development of a comprehensive model using **[O] at turndown** from the **sub-lance measurements**.
  - Extensive plant trials and model implementation in level 2 automation.
- **Reduction of metal losses during raking in the external Desulphurization unit in LD 2 plant (Member)**
  - Data acquisition from the plant on the metal losses during raking over the last 1 year.
  - Extensive plant trials with additions of **glass and/or lime pellet** and subsequent recommendations.

- **Establishing Heat Transfer and Solidification behavior of peritectic and low-carbon steels (Member)**
  - Development of Peritectic range predictor using **ThermoCalc** analyses and heat flux data
  - Measurement of hot ductility of solidified shell using **Gleeble**
  - Determination of shell thickness through actual temperature measurements along the mold length.
- **Masters Dissertation, IIT Bombay** [Jan 2012-June 2013]

*Dissertation Title: Dynamic modeling of LD convertor steelmaking*

  - *Decarburization kinetics* of high carbon *Fe-C droplets* in slag
  - Effects of the amount of **FeO** in slag, *droplet size* and *temperatures* on **decarburization rate**
  - *Mathematical model* to predict the composition and temperature of the metal and slag
  - *Mixing* characteristics of the bath by diving it into a two- reactor model
  - Effects of *metal exchange rate* and the *reactor size ratio* on mixing properties of bath
- **Undergraduate project, Jadavpur University** [May 2010-May 2011]

*Project Title: Isothermal and non-isothermal kinetics of Magnetite reduction by coking coal*

  - Generated *kinetic data* for magnetite reduction in the range **900°C-1100°C**.
  - Qualitative interpretation of kinetic data obtained under *isothermal* and *non-isothermal* conditions
  - Predicted the reaction mechanism to be “*Interfacial Reaction Control*” using ‘*reduced time plots*’
  - Calculated an average activation energy of the reaction using *Arrhenius plots*
- **Summer Intern project, NML Jamshedpur, India** [May’2010-July’2010]

*Project Title: Examples of process analysis in metal extraction using Factsage*

  - Calculated *Standard Gibbs’ Free Energy Changes*( $\Delta G^0$ s) for reactions pertinent to **Mg extraction**
  - Constructed *binary, ternary* and *quaternary* phase diagrams for **MgO-CaO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>** system
  - Determined the theoretical *slag-metal equilibrium* composition for **Fe-Mn** production
  - Examined the *common errors* while using *Factsage* and suggested *methods* to get reliable information

### Teaching Experience

- **Teaching Assistant, University of Utah** [Aug’2016-Dec’2016]
  - *High Temperature Chemical Processing (MET E 5760/6760)*

- Preparation of lecture notes and laboratory hand-outs for a class of 20, consisting of both undergraduate and graduate students
  - Grading of homework assignments and preparation of model solutions for homework problems
  - Organizing laboratory classes for the students and demonstration of laboratory procedures
  - Evaluation of mid-term and final examination answer scripts and participation in final grading
- **Teaching Assistant, IIT Bombay** *[Jan'2012-May'2013]*
    - Undergraduate course on *Thermodynamics of Materials (MM 202)* for *Spring 2012*
    - Graduate course on *Transport Phenomena (MM 659)* for *Fall 2012*
    - Graduate course on *Advanced Steelmaking (MM 624)* for *Spring 2013*

### Conference Participation

- *AISTech 2019-The Iron and Steel Technology Conference and Exposition* held in Pittsburgh, PA from May 6-9, 2019. *[May'2019]*
- *Materials Science & Technology (MS&T) 2019* held in Portland, OR from September 29-October 3, 2019. *[September'2019]*
- Second international conference on “*Science and Technology of Ironmaking and Steelmaking (STIS-2013)*” held in NML, JSR from Dec. 13-16, 2013. *[December' 2013]*
- Fourth “*National Symposium for Materials Research Scholars, MR-12*” held in IIT, Bombay from May 3-5, 2012. *[May'2012]*

### Relevant Skills

- High temperature experimentation using *horizontal* and *vertical tubular furnaces and confocal scanning laser microscopy (CSLM)*.
- Experience in the operation of *Large Scale Bench Reactor (LSBR)* for flash ironmaking in *University of Utah*.
- Analytical tools: *XRD, Scanning Electron Microscopy (SEM)* and *Optical Microscopy (OM)*, *thermal analysis techniques such as DSC-TGA, Electron Probe Microanalyzer (EPMA)* and *Nano-indentation*.
- Software Skills: *ThermoCalc, Factsage, Matlab, Avizo*.